Understanding Television's Grade A and Grade B Service Contours

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Abstract—The Grade A and Grade B service contours of a television broadcast station are used for a host of administrative purposes by the FCC including the regulation of CATV systems. Additionally, the contours are used by most stations for promotional and marketing purposes. The numerical values associated with these contours represent levels of field strength; consequently, assumptions were made in their determination as to noise limitation, the antenna gain, and transmission-line loss of the receiving system. Also, consideration was given to the subjective nature of picture quality and the statistical variation of field strength with time and location. The nature of these variables is discussed and the assumed values are tabulated in a format suitable for easy understanding and for analysis of possible future changes.

Introduction

THE Grade A and Grade B iso-service contours associated with television broadcast stations have been in existence for over fifteen years and have become familiar expressions to almost everyone in the industry. The contours are referred to in the FCC's Rules and Regulations, but very little is said of their true significance or their original development.

In recent years these contours have been used by the FCC for many purposes not envisaged at the time of their adoption. Perhaps the most important of these purposes is the application of the carriage, nonduplication, and importation requirements for CATV systems.

This paper presents the development of the Grade A and Grade B contours in a hopefully more complete and understandable fashion than has been done heretofore. This may prove helpful to those long in the industry who have forgotten their derivation, as well as for those who may be encountering Grade A and Grade B contours for the first time in connection with CATV activity.

Basic Considerations

Every prospective licensee for a television broadcast station is required to file with the FCC, as one of the many exhibits called for in the application for Construction Permit, a map on which has been plotted the predicted Grade A and Grade B contours. The contours are calculated in accordance with a very specific procedure which is described in Section 73.684 of the FCC Rules and Regulations. The procedure involves the calculation, from topographic maps, of the average terrain elevation, from two to ten miles from the transmitter, in eight specific directions, plus one more direction if none of the eight directions should include the principal community. The height of the electrical center of the antenna above this average terrain then determines the effective height. This height together with the effective radiated power can be used to determine the distance to any specific value of field strength, such as the values associated with the Grade A and Grade B contours, using the field strength charts of Section 73.699. As an example, if the effective height so determined were 1000 feet and the effective radiated power were 100 kW for a Channel 2 station, the distance to the Grade A contour (68 dBu) would be 37 miles and the distance to the Grade B contour (47 dBu), 70 miles, as read on the Fig. 9 chart of Section 73.699. After two such points are determined for each radial, they are then plotted on a map, usually a sectional aeronautical chart, and joined together in two continuous lines to form the two contours. Fig. 1 shows such a map for KNXT, Channel 2, Los Angeles, Calif.

In addition to the specific field strength values for these two contours, the Rules and Regulations also specify a "minimum field intensity" which must be provided over the entire principal community to be served. The numerical value of this contour is 6-dB higher than Grade A. Although not specifically requested as a contour in the application, quite often many applicants will include this value as an additional contour labelled the "city grade contour." In fact, the FCC itself uses this terminology in many of its proceedings.

The Rules and Regulations indicate that these contours are to be used for rough estimates of coverage as well as for certain administrative purposes. In addition to these "official" uses, most stations use these maps for promotional purposes as an indication of their service or market areas.

The current Rules and Regulations contain very little information on the meaning of these contours. However, the basic data that were used to derive them are contained in the background information which led to the establishment of the present television broadcast service, specifically in the "Third Report," FCC Rept. 51-244, which was adopted March 21, 1951. Since the numerical values associated with these contours are in terms of *field strength*, in dB above 1 μV/m (abbreviated dBu) at 30 feet above ground, some as-

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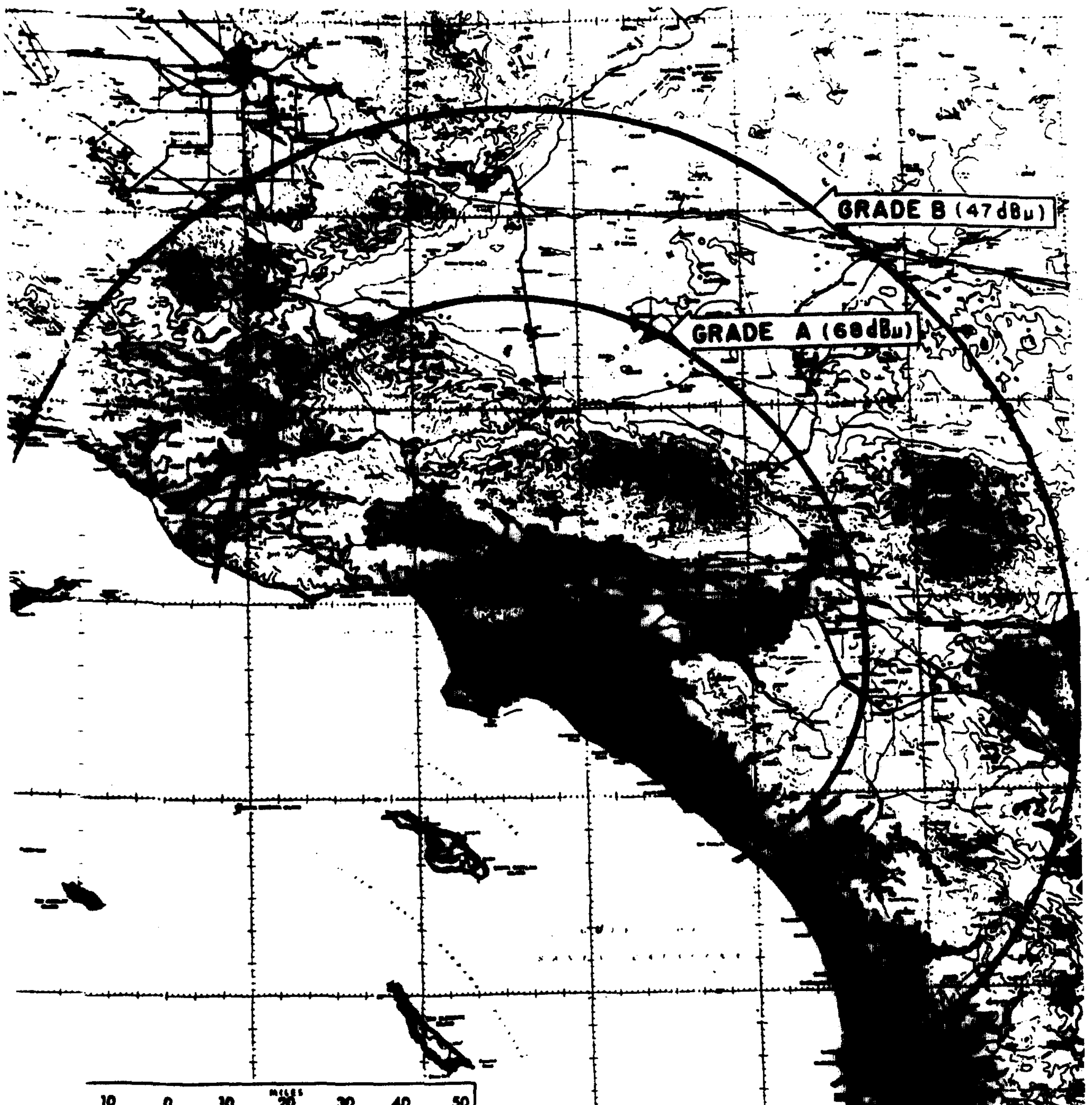

Fig. 1. Predicted Grade A and Grade B contours for KNXT, Channel 2, Los Angeles, Calif.

sumption are obviously made with respect to the home viewer's receiving installation (antenna gain, line loss, and receiver noise figure). This is so since it is the signal voltage, at the receiver terminals, which together with the noise or interference limitation determines whether or not a picture of any given quality will be produced on the picture tube. Since quality is a subjective parameter, an assumption must also be made as to the criticalness of the viewer, whether average or, for example, one who is more or less discerning than the average viewer. Also, since field strength may vary with time and with location, even between points relatively close together, assumptions must be made with respect to statistical levels of the two parameters, percentage of time, and percentage of locations.

Definitions of Grade A and Grade B Service

Assumptions with respect to all these aforementioned parameters have been made in establishing the Grade A and Grade B levels of service, and if described fully, these levels could be defined as follows:

Grade A represents a specific value of ambient median field strength existing 30 feet above ground which is deemed to be sufficiently strong, in the absence of interference from other stations, but with due consideration given to man-made noise typical of urban areas, to provide a picture which the median observer would classify as of "acceptable" quality, assuming a receiving installation (antenna, transmission line, and receiver) considered to be typical of suburban or not too distant areas. This signal level is sufficiently strong to provide such a picture at least 90 percent of the time, at the best 70 percent of receiving locations. The Grade A contour represents the outer geographic limits within which the median field strength equals or exceeds the Grade A value. The specific values for Grade A are 68 dBu (2.5 mV/m) for Channels 2 to 6, 71 dBu (3.5 mV/m) for Channels 7 to 13, and 74 dBu (5.0 mV/m) for Channels 14 to 83.

Grade B represents a specific value of ambient median field strength existing 30 feet above ground which is deemed to be sufficiently strong, in the absence of man-made noise or interference from other stations, to provide a picture which the median observer would classify as of "acceptable" quality, assuming a receiving installation (antenna, transmission line, and receiver) considered to be typical of outlying or near-fringe areas. This signal level is sufficiently strong to provide such a picture at least 90 percent of the time, at the best 50 percent of receiving locations. The Grade B contour represents the outer geographic limits within which the median field strength equals or exceeds the Grade B value. The specific values for Grade B are 47 dBu (0.22 mV/m) for Channels 2 to 6, 56 dBu (0.63 mV/m) for Channels 7 to 13, and 64 dBu (1.6 mV/m) for Channels 14 to 83.

Although "acceptable" quality is not further defined in the background material leading to these standards, the assumed signal-to-noise ratio (S_{nr}) of 30 dB would indicate a quality similar to that described by the Television Allocation Study Organization (TASO) as Grade 3 or "passable," which is described as follows: "The picture is of acceptable quality. Interference is not objectionable."

With respect to "city grade service," no comparable statistics are included in the aforementioned reference, but presumably this would entail the same quality of picture, which would be available to a higher percentage of locations and/or a higher percentage of the time, in the face of an even poorer receiving antenna and/or more severe man-made noise limitation.

Development of Field Strength Requirements

Before discussing the actual values of the various parameters which have been mentioned above, it will be helpful to review the process by which ambient field strength is converted to voltage across the receiver terminal. Actually there is a very simple relationship

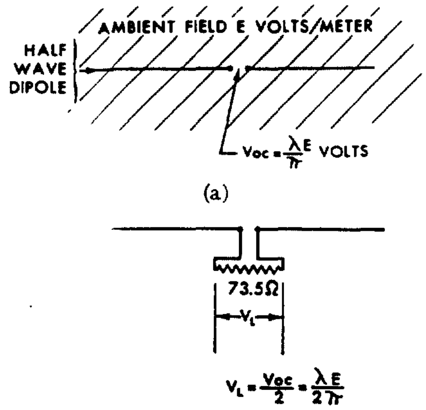

Fig. 2. Relationship between field strength and terminal voltage.

that relates these two parameters, known as the "effective length" of the antenna, which for a reference half-wave dipole antenna is numerically equal to λ/π meters. As indicated in Fig. 2(a), a half-wave dipole receiving antenna in an ambient field of E volts per meter will generate an open circuit voltage V_{oc} at its terminals, which is numerically equal to $E\lambda/\pi$ volts.

Maximum transfer of energy from the antenna terminals to a load occurs when the impedance of the load is equal to the impedance of the source, which for the half-wave dipole is approximately 73.5 ohms. Referring to Fig. 2(b), if an impedance of 73.5 ohms is connected to the antenna terminals, maximum energy transfer would occur and the voltage across the load would become $V_{oc}/2$ or $E\lambda/2\pi$ volts.

For further convenience in discussing the factors used to arrive at the numerical values for service contours, it is helpful to use a factor which relates ambient field to voltage across a 300-ohm load, which is the nominal impedance of a television receiver, as a function of frequency. Substituting $300/F$ (MHz) meters for λ in the above expression and transforming the impedance base by the square root of the ratio of the 300 ohms to 73.5 ohms, the expression for V_L becomes

$$V_{300} = \frac{300}{2\pi F_{\mathrm{MHz}}} \sqrt{\frac{300}{73.5}} \times E = \frac{96.5}{F_{\mathrm{MHz}}} \times E .$$

Since it has become the standard practice to express allocation planning parameters in dB terms, the expression 20 log $96.5/F_{\mathrm{MHz}}$ has been used as one of these parameters and called the "dipole" or "lambda" factor, K_d. (It should be recognized that this is not a true ratio but has the dimension of length. However, although not rigorously correct, it is convenient to use the expression since all of the other parameters are expressed, and correctly so, in dB terms.)

For allocation planning purposes, the FCC used a single value of K_d based on the geometric mean frequency of the three blocks of frequencies involved:

Channels	Geometric Mean Frequency (MHz)	K_d (dB)
2 to 6	69	3
7 to 13	194	−6
14 to 83	645	−16

As an interesting aside, this is a clear indication of one of the reasons why UHF stations are permitted so much more radiated power than VHF stations. Based on the above figures, the field strength from a UHF station would have to be 19 dB greater than the field strength from a low-band VHF station to produce the same terminal voltage across a receiver, assuming equal receiving antenna gains and equal transmission line losses.

The effects of receiving antenna gain and line losses may be considered by expanding the basic equation as follows:

$$V_L = E + K_d + G - L$$

where

- V_L = voltage across the receiver terminals, conventionally expressed in dB above 1 μV/m or dBu
- E = ambient field strength, conventionally expressed in dB above 1 μV, which unfortunately is also abbreviated as dBu
- K_d = dipole factor in dB
- G = antenna gain in dB referenced to a half-wave dipole
- L = transmission-line system loss in dB.

With respect to L, this is generally referred to as line loss, but in arriving at an appropriate value, consideration should be given to other sources of loss in the interconnection between antenna and receiver, such as couplers, baluns, splitters, and the mismatch because the impedance of the receiver is not exactly $300+j0$ ohms.

Having determined the "signal," it is now necessary to determine the "noise" since as in any communication system it is the ratio of these two parameters which determine whether or not service of a given quality will be available.

In the frequency range under consideration, the principal sources of noise are man-made noise (caused by ignition systems, power distribution, neon signs, diathermy, industrial equipment, household appliances, etc.), interference from other stations operating on the same and adjacent channels, and, of course, receiver noise. In the absence of external noise, the ultimate limit to receiver sensitivity is the thermal noise generated in the receiver itself. The analysis that follows will be based on receiver noise limitation. As indicated, this is the assumed limitation for the Grade B contour (in the absence of interference from other stations), which is generally regarded as the more significant contour since it represents an approximate estimate of the extent of a television station's service area.

Receiver noise may be determined in two steps by considering 1) the inherent thermal noise voltage N_I generated across the terminals of an ideal receiver, and 2) the noise figure of the receiver N_R which is a figure of merit indicating how much greater the actual receiver noise voltage is compared with the noise voltage in the ideal receiver.

Assuming that the receiver can be represented by its input resistance and that a matched load will be connected across its terminals, the noise voltage appearing at these terminals, so loaded, is represented by the following expression:

$$N_I = 20 \log \sqrt{kTRB}$$

where

- k = Boltzmann's constant, 1.38×10^{-23} W/°K·Hz
- T = circuit temperature in °K
- B = bandwidth in hertz
- R = input resistance in ohms.

Substituting 290° for T (room temperature), 4×10^6 Hz for B, and 300 ohms for R, this noise voltage becomes 2.19 μV, or approximately 7 dBu. Thus the total noise voltage generated in the receiver is the sum of 7 dBu$+N_R$.

In determining values of field strength required to constitute a given quality of service, we must provide for sufficient margin above the noise to insure this quality. For both Grade A and Grade B, the FCC has assumed such a margin, or signal-to-noise ratio, which for an amplitude modulation system is synonomous with carrier-to-noise ratio, of 30 dB. As indicated earlier, this is roughly comparable to the ratio corresponding to the aforementioned Grade 3 (passable) picture as determined in the subsequent TASO studies.

The results of the TASO studies on this topic, which are summarized in Fig. 3,[1] show very clearly the very *subjective* aspects of this determination. Note, for example, that while the median observer indicated the picture was "passable" when the S_{nr} was 28 dB, the lower 10 percent of the observers felt this condition existed when the S_{nr} was only 22 dB, and the upper, most discriminating, 10 percent required a 34 dB S_{nr} before they rated the picture "passable."

Inherent in the definitions of Grade A and Grade B is the variable nature of received VHF and UHF field strengths with location and with time. Both definitions involve a percentage of locations and a percentage of time. Consequently, to complete the analysis, these two factors must be considered.

[1] This figure is based on TASO data reprinted in H. Fine, "A further analysis of TASO Panel 6 data on signal to interference ratios and their application to description of television service," FCC Rept. TRR 5.1.2, April 1, 1960, Fig. 1.

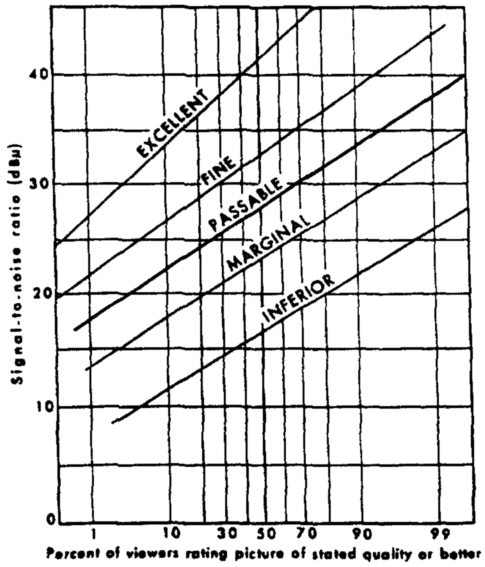

Fig. 3. Required signal-to-noise ratio based on random noise.

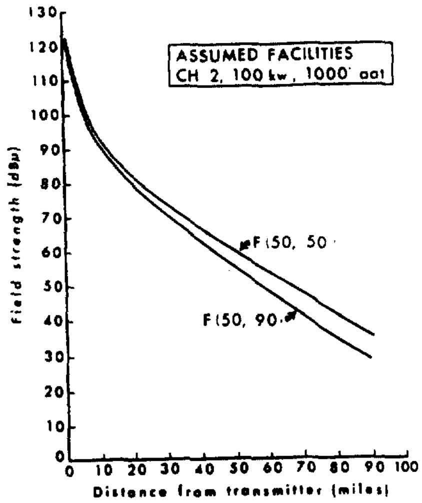

Fig. 4. Example of time fading.

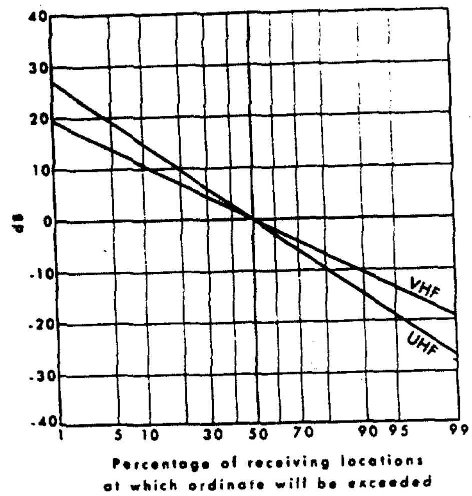

Fig. 5. Location distribution.

Time and Location Probabilities

It is a well-known phenomenon that VHF and UHF fields vary with time, diurnally and seasonally, at a given location. This variation will be different depending upon frequency, antenna height, and distance from the transmitter. Much empirical data has been developed to chart these variations and it has become the convention to employ a time-fading factor ΔT which represents the difference in dB between the median field strength, the field strength exceeded 50 percent of the time, and the field strength exceeded for some other percentage of the time.

As an example of this variation, Fig. 4 shows the F (50,50), meaning the field strength exceeded at 50 percent of the locations for 50 percent of the time, and the F (50,90), meaning the field strength exceeded at 50 percent of the locations for 90 percent of the time, propagation curves for a specific assumed facility, namely, a low-band station operating with 100 kW ERP at an effective height of 1000 feet above average terrain. Note that at 70 miles, the distance to the Grade B (47 dBu) contour, the difference between the two fields is approximately 6 dB. Consequently, if the basic curves being used are the F (50,50) curves and it is desired to describe a service that would exist for 90 percent of the time, the field strength objective would have to be increased by 6 dB. Incidentally, the F (50,90) curves on which this chart was based[2] have never been incorporated in the Rules and Regulations. The Rules and Regulations include only the F(50,50) curves.

[2] Based on the "June 1960" curves issued by the FCC in connection with Docket 13 340, "In the matter of interim policy on VHF television channel assignments and amendment of Part 3 (now Part 73) of the Rules concerning television engineering standards," initially adopted January 4, 1960.

It is an equally well-known phenomenon that VHF and UHF fields vary with location at any given distance from the transmitter. By virtue of the relatively short wavelengths involved, it is quite common for the field strength to vary several dB over a relatively short distance of a few yards. This variation is a function of frequency and terrain, increasing as the frequency increases and decreasing as the terrain becomes more smooth. This phenomenon can be predicted in a generalized way with reasonable accuracy since it has been found that received field strength over a short distance follows a pattern described by a lognormal distribution. Since field strength is conventionally expressed in dB terms, field strength values so expressed will follow a normal distribution which can be represented by the familiar bell-shaped curve, or if plotted on arithmetic probability paper, by a straight line. Here again this effect can be represented by a location probability factor which shall be represented as ΔL in this paper. This factor represents the difference in dB between the median field, the field exceeded at 50 percent of the locations, and the field exceeded for some other percentage of the locations.

This location distribution is shown in Fig. 5. Note, for example, that the difference between the median and the 70 percent point is approximately 4 dB for VHF and 6 dB for UHF. Consequently, for use in conjunction with the F (50,50) curves, a field strength objective would have to be increased by these values to describe service which would be available at 70 percent of the locations.

Remembering that the numerical values associated with the Grade A and Grade B contours represent ***field strength***, and that field strength differs from receiver voltage E by the dipole factor K_d, we can rearrange the basic equation in the form that was used to develop the Grade A and Grade B values:

$$E = N_I + N_R + S_{nr} - K_d - G + L + \Delta T + \Delta L.$$

Propagation Curves

Having determined the field strength required for Grade A and Grade B service, the ultimate objective is to determine the maximum distance from the transmitter at which this value of ambient field will exist. Knowing the heights of the transmitting and receiving antennas, and the effective radiated power, this distance could be calculated using theoretical formulas, such as the plane earth equation or the smooth spherical earth equation. However, the standard FCC procedure involves the use of ***empirical*** propagation curves which are included in the Rules and Regulations as Figs. 9 and 10 of Section 73.699. These curves have been developed on the basis of extensive measurements, corrected to reflect ***average terrain*** conditions, meaning gently rolling countryside. The Rules and Regulations indicate that true coverage may vary greatly from estimates thus obtained if the terrain differs from this average terrain. These curves represent median location and time values and are labeled F (50,50). If it is desired to specify service for different percentages of location and time, F (50,50) curve values are adjusted in accordance with the ΔT and ΔL factors previously described. It should be noted further that these curves assume a receiving antenna height of 30 feet which is considered typical of the average home installation and has become the industry standard. (There are methods of adjusting the values obtained from these curves to reflect other receiving antenna heights, but none of these techniques are completely satisfactory.)

Determination of Grade A and Grade B Values

Listed below are the actual values assumed by the FCC in their derivation of the numerical values for Grade A and Grade B. It will be noted that in the case of Grade A for VHF channels, a greater signal than calculated is required to constitute the assumed level of service in order to overcome local noise and interference under urban conditions. (The basis for these noise and interference limitations will not be covered in this paper.)

Grade A

Parameter	Sign	Channels 2 to 6	Channels 7 to 13	Channels 14 to 83
N_I (dBu)	+	7	7	7
N_R (dB)	+	12	12	15
S_{nr} (dB)	+	30	30	30
K_d (dB)	−	3	−6	−16
G (dB)	−	0	0	8
L (dB)	+	1	2	5
ΔT 90 percent (dB)	+	3	3	3
ΔL 70 percent (dB)	+	4	4	6
1) Totals		54 dBu	64 dBu	74 dBu
2) Median field strengths required to overcome local noise and interference under urban conditions		68 dBu	71 dBu	74 dBu
3) Required field strengths to overcome 1) or 2) (whichever is greater) Grade A values		68 dBu	71 dBu	74 dBu

Grade B

Parameter	Sign	Channels 2 to 6	Channels 7 to 13	Channels 14 to 83
N_I (dBu)	+	7	7	7
N_R (dB)	+	12	12	15
S_{nr} (dB)	+	30	30	30
K_d (dB)	−	3	−6	−16
G (dB)	−	6	6	13
L (dB)	+	1	2	5
ΔT 90 percent (dB)	+	6	5	4
ΔL 50 percent (dB)	+	0	0	0
Grade B values		47 dBu	56 dBu	64 dBu

Obviously, many of these factors represented considered judgments at the time of the "Third Report" in 1951. Although some observers might take exception to individual entries, most will agree that the estimates are reasonable and have fulfilled many useful functions, since they do represent a standard which can be uniformly applied. As an example of such possible exceptions, most receivers now have noise figures considerably better than indicated. This is particularly true in the outlying areas where the use of low-noise, moderate-gain antenna-mounted preamplifiers can reduce these figures by as much as 6 dB. Recognizing that a reevaluation may be in order, the FCC in recent years has considered alternate standards for service contours[3] and is currently considering changes in the basic propagation curves.[4]

[3] As part of Docket 13 340, the FCC considered the establishment of two new service contours based on "normal service" (passable picture, set noise limited, 50 percent of the locations, 90 percent of the time) and "principal city service" (excellent picture, man-made noise limited, 90 percent of the locations, 90 percent of the time).

[4] Docket 16 004, "In the matter of Sections 73.333 and 73.699 field strength curves for FM and TV broadcasting stations."

Conclusion

In addition to providing an understanding of the factors involved in the Grade A and Grade B contours, the tabular summary developed in this paper can form a frame of reference for the analysis of possible subsequent proposed changes in the various parameters.

Acknowledgment

The author wishes to express his appreciation to H. A. Chinn, Director of General Engineering, Engineering and Development Department, CBS Television Network, for his many helpful suggestions concerning the preparation of this paper.

Automatic Control of Loudness Level

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***Abstract*—A loudness limiter which reduces disparity in loudness levels, when a program is controlled on a vu basis, has been developed by CBS Laboratories. The device evaluates the loudness level of the program by a "loudness level summation" method described previously by the authors, and automatically reduces the program level when a preset threshold is exceeded.**

Introduction

FOLLOWING the successful development of a Loudness Indicator[1] for monitoring audio loudness levels, a new automatic device has now been developed for controlling these levels. The Automatic Loudness Controller adjusts system gain in a manner similar to that of compressors or peak limiters. However, whereas in these latter devices the criterion for control is volume or modulation level, the Automatic Loudness Controller acts only to limit excessive loudness.

The need for such a device has been clearly established. Listener complaints of unpleasantly loud commercials have been increasing at a steady rate, especially in television broadcasting, for at least ten years. Three years ago, the problem even attracted Congressional attention. Finally, in 1965 the FCC revised its standards to require that modulation levels be "usually not less than 85 percent on peaks of frequent recurrence, but where necessary to avoid objectionable loudness, modulation may be reduced to whatever level is necessary."[2]

The intention of the rules change was quite clear, but actual performance to this standard was very difficult. As pointed out in the previous paper,[1] the vu meter does not adequately measure the loudness level. Without automatic controllers or measuring devices, the broadcaster could only listen to the program and hope that his judgment was good. Unfortunately, even if he were able to make good level adjustments manually at the broadcast studio, the peak limiter at the remote unattended transmitter site would probably undo all his conscientious efforts.

In response to this urgent problem, CBS Laboratories began a three-year program of research and development which has now resulted in prototype designs for a Loudness Indicator and an Automatic Loudness Controller. It is the purpose of this paper to share with the reader some of the most important design considerations in the development of the loudness controller.

Operational Requirements

A basic decision had to be made regarding the philosophy of use of a loudness controller. There are two possibilities. It could be similar in concept to a level control or compressor, i.e., it would reduce the overall loudness range rather slowly by raising the level of soft passages and reducing the level of loud ones. In this mode of operation, it would probably be used at the output of a mixer or console. Alternatively, the device could be a loudness *limiter*, responding rapidly to reduce loudness level, but never increasing signal gain beyond previously established levels. It is easy to understand why the latter choice is preferred. The loudness controller must be the last variable gain device in a program channel because any following unit would defeat its purpose. Furthermore, since this means that the loudness controller follows the peak limiter, no upward automatic gain increase can be tolerated, because this would cause overmodulation.

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The authors are with CBS Laboratories, Stamford, Conn.

[1] B. B. Bauer, E. L. Torick, A. J. Rosenheck, and R. G. Allen, "A loudness-level monitor for broadcasting," *IEEE Trans. Audio and Electroacoustics*, vol. AU-15, pp. 177–182, December 1967.

[2] FCC Rules and Regulations, vol. 3, paragraphs 73.55, 73.268, 73.687 (b) (7), as amended effective January 1, 1965.

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A REVIEW OF THE TECHNICAL PLANNING FACTORS FOR VHF TELEVISION SERVICE

RESEARCH & STANDARDS DIVISION
OFFICE OF CHIEF ENGINEER

MARCH 1, 1977

FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C. 20554

INTRODUCTION

As a result of issues raised in the proceedings in Docket 20418 (VHF-TV "Drop-ins"), a review of the planning factors pertinent to the determination of coverage areas, interference criteria and minimum separation requirements of adjacent and co-channel VHF-TV stations was deemed desirable. The values of these planning factors were originally established in the Third Notice(1/) and Sixth Report and Order in Docket 8736, et al(2/), adopted April 11, 1952. Since then there have been several proposals to revise some of the values (3/)(4/). The current review indicates that many of the original values are still valid, some need updating and others are questionable but current values are uncertain at this time.

The purpose of this report is twofold:

(1) To make available in one document the values, definitions, explanations and sources of the original planning factors. An extensive bibliography is included for those who might wish more detailed explanations of specific factors.

(2) To identify those factors whose values should be updated because of technological advancements (e.g., receiver noise figures), re-evaluation of physical phenomena (e.g., new propagation curves), changes in environmental factors (e.g., higher man-made noise levels) or changes in the Commission's policies.

While new values are proposed for several of the planning factors no evaluation is presented concerning the effect these changes may have on the predicted coverage range and minimum separation requirements of TV stations. Before changes in these distances are entertained, all of the proposed new values should be discussed more widely and more information should be collected on some. And, finally, it is recognized that public policy considerations beyond the scope of this report must play an important role in this determination.

Present Grades of Service

The Commission in its Sixth Report and Order adopted two grades of service. Grade A service is such that the median field strength provides a picture which is "acceptable" to the median observer for at least 90% of the time at the best 70% of the receiving locations. The Grade A contour is the geographic boundary within which the median field strength is equal to or greater than the Grade A value. Grade B service is such that the median field strength provides a picture which is "acceptable" to the median observer for at least 90% of the time at the best 50% of the receiving locations. The Grade B contour is the geographic boundary within which the median field strength is equal to or greater than the Grade B value. Table 1 gives the required values of median field strength in db above one microvolt per meter.

Table 1
Median Field Strengths

Grade of Service	Channels 2-6	Channels 7-13
A	68 db	71 db
B	47 db	56 db

In the presence of a co-channel interfering signal, the service contours are expressed as interference ratios in db of median desired field strengths to 10% undesired field strengths. Table 2 gives the required interference ratios.

Table 2
Co-Channel Interference Ratios

Grade of Service	Channels 2-13	
	Non Offset Freq.	Offset Freq.
A	51 db	34 db
B	45 db	28 db

Grade A service assumes a "typical" receiving installation located within a "typical" urban area with some man-made noise present.

Grade B service assumes a "typical" receiving installation located within a "typical" noise-free rural area.

The Grade A and B values were determined by specifying the field strength necessary to overcome noise taking into consideration losses in receiving components, location variability and time fading. The procedure is shown in Tables 3A and 3B.

Table 3A
Grade A Factors

Factors	Units	Channels 2-6	Channels 7-13
1. Thermal Noise (@300 ohms)	db/luv	7	7
2. Receiver Noise Figure	db	12	12
3. Peak vis. Car./RMS Noise	db	30	30
4. Trans. Line Loss	db	1	2
5. Rec. Antenna Gain	db	0	0
6. Dipole Factor	db	-3*	6
7. Local Field F(70,90)	db/luv/m	47	57
8. Terrain Factor (70%)	db	4	4
9. Time Fading Factor (90%)	db	3	3
10. Median Field F(50,50)	db/luv/m	54	64
11. To Overcome Urban Noise	db	14	7
12. Required Median Field	db/luv/m	68	71

*Note: Since this is a table of losses, a gain appears a negative quantity.

Table 3B
Grade B Factors

Factors	Units	Channels 2-6	Channels 7-13
1. Thermal Noise (@300 ohms)	db/luv	7	7
2. Receiver Noise Figure	db	12	12
3. Peak vis. Car./RMS noise	db	30	30
4. Trans Line Loss	db	1	2
5. Rec. Antenna Gain	db	-6	-6
6. Dipole Factor	db	-3	-6
7. Local Field F(50,90)	db/luv/m	41	51
8. Terrain Factor (50%)	db	0	0
9. Time Fading Factor (90%)	db	6	5
10. Median Field F(50,50)	db/luv/m	47	56
11. To Overcome Rural	db	0	0
12. Required Median Field	db/luv/m	47	56

The transmission line was assumed to be 50 feet of 300 ohm twinlead. The antenna gains are with reference to a half-wave dipole. The dipole factor is defined as a quantity in db which when subtracted from the voltage in db above one microvolt across the 300 ohm impedance of a television receiver gives the equivalent field strength, in db above one microvolt per meter of the field in which a half-wave dipole receiving antenna is located.

The expression for the dipole factor is;

$$20 \log_{10} \left[\frac{96.68}{F} \right]$$

where, F is the frequency in MHz.

The values given in tables 3A and 3B for the dipole factor assume for F the geometric mean frequency for each channel range.

A derivation of the expression is found in Appendix A.

<u>Prediction of Service Field Strengths</u>

The minimum field strength available at any percentage of receiving locations for any percentage of time may be described by the following equation;

$$F'(L,T) = P' + F(50,50) + R(L) + R(T)$$

where, $F'(L,T)$ = the minimum field strength at L% of locations for T% of time in db/1uv/m.
P' = the effective radiated power in db/1Kw from a halfwave dipole.
$F(50,50)$ = the minimum field at 50% of the locations for 50% of the time in db/1uv/m for a radiated power of 1Kw
$R(L)$ = the terrain distribution factor for L% of locations.
$R(T)$ = the time distribution factor for T% of time.

Values for F(50,50) and F(50,10) as a function of distance and transmitting antenna height above average terrain are found in Part 73.699 of the Commission's <u>Rules</u>.

Log normal distributions for the factors R(T) and R(L) are shown in Figure 1. The time distribution factor, R(T), is found from

$$R(T) = R(T = 10)\ K(T)$$

Where, $K(T)$ = shown in figure 1 as a function of time.
$R(T=10)$ = the time factor for fields exceeded for 10% of time. and is found by subtracting the value exceeded for 50% of the time from the value exceeded for 10% of the time.

$$R(T=10) = F(50,10) - F(50,50)$$

With the adoption of the new propagation curves, new values of R(T=10) should be used to calculate the time fading factors in tables 3A and 3B. New values of R(T=10) vs. distance from the transmitter are shown for channels 2-13 in figure 10 of FCC report R-6602. (6/) This figure is reproduced in Appendix B.

Technical Planning Factors

All of the planning factors, including suggested new values, are shown in Tables 4A and 4B, and discussed below.

1. Antenna Height above Average Terrain

In the Sixth Report, a value of 500 ft. was assumed in the calculations for all channels in all zones. The use of greater antenna heights was encouraged, but the effective radiated power had to be limited to that value which would avoid interference within the Grade A service radius of any other assignment assuming an antenna height of 500 ft.for the assignment. The values shown in the tables are the maximum allowed in Part 73 of the Rules.

2. Geometric Mean Frequency

The geometric mean frequency is calculated as shown below.

Channel Range	Frequency Range	Geo. Mean Freq.
2-6	54-88 MHz	$\sqrt{(54)(88)} = 69$ MHz
7-13	174-216 MHz	$\sqrt{(174)(216)} = 194$ MHz

3. Power

In The Sixth Report & Order, the Commission adopted values of 100 kilowatts (20dbk) for channels 2-6 and 316 kilowatts (25dbk) for channels 7-13.

5. Thermal Noise Voltage

The thermal noise power at the input of a TV receiver for a matched load is given by;

$$P = k\,T\,B$$

Where,

k = Boltzmann's constant (1.38×10^{-23} joule/$^{\circ}$K)
T = temperature in $^{\circ}$K (290)
B = bandwidth in hertz (4×10^{6} Hz)

assuming the above values, $P = 1.6 \times 10^{-14}$ watts
and for an impedance of 300 ohms, the noise voltage is 7 db above one microvolt.

Technical TV Planning Factors For the Determination of Grade A Service

	Grade A Factor	Units	Channels 2-6 Zone I	Channels 2-6 Zone II & III	Channels 7-13 Zone I	Channels 7-13 Zone II & III
1.	Hgt. above avg terrain	feet	1000	2000	1000	2000
2.	Geometric Mean Freq.	MHz	69	69	194	194
3.	Power	dbK	20	20	25	25
4.	Service Grade		A	A	A	A
5.	Thermal Noise	db/uV	7	7	7	7
6.	Receiver Noise	db	6	6	7	7
7.	Vis. peak/RMS Noise	db	30	30	30	30
8.	Line loss	db	2	2	3	3
9.	Rec. Antenna Gain	db	0	0	0	0
10.	Dipole Factor	db	-3	-3	6	6
11.	Location Prob. (L)	%	70	70	70	70
12.	Local Field F(L,90)	dbuV/m	42	42	53	53
13.	Location Prob. Factor	db	4	4	4	4
14.	F(50,90) field	dbuV/m	46	46	57	57
15.	Time Prob.	%	50	50	50	50
16.	Time Prob. Factor	db	7	8	6	7
17.	F(50,50) field	dbuV/m	53	54	63	64
18.	To overcome Urban Noise	db	14	14	7	7
19.	To overcome Rural Noise	db	0	0	0	0
20.	Atmospheric Noise	db	9	9	0	0
21.	Required Med. Field	dbuV/m	67	68	70	71
22.	Rec. Ant. F/B ratio	db	0	0	0	0
23.	D/U Ratio no offset	db	51	51	51	51
24.	D/U Ratio offset	db	34	34	34	34
25.	D/U Ratio Precise off	db	30	30	30	30
26.	Adj. Chan. D/U Ratio (Low)	db	-6	-6	-6	-6
27.	Adj. Chan. D/U Ratio (UP)	db	-12	-12	-12	-12

TABLE 4A

Technical TV Planning Factors For the Determination of Grade B Service

Grade B Factor	Units	Channels 2-6 Zone I	Channels 2-6 Zone II & III	Channels 7-13 Zone I	Channels 7-13 Zone II & III
1. Hgt. above avg terrain	feet	1000	2000	1000	2000
2. Geometric Mean Freq.	MHz	69	69	194	194
3. Power	dbK	20	20	25	25
4. Service Grade		B	B	B	B
5. Thermal Noise	db/uV	7	7	7	7
6. Receiver Noise	db	6	6	7	7
7. Vis. peak/RMS Noise	db	30	30	30	30
8. Line loss	db	2	2	3	3
9. Rec. Antenna Gain	db	-6	-6	-6	-6
10. Dipole Factor	db	-3	-3	6	6
11. Location Prob. (L)	%	50	50	50	50
12. Local Field F(L,90)	dbuV/m	36	36	47	47
13. Location Prob. Factor	db	0	0	0	0
14. F(50,90) field	dbuV/m	36	36	47	47
15. Time Prob.	%	50	50	50	50
16. Time Prob. Factor	db	8	9	7	9
17. F(50,50) field	dbuV/m	44	45	54	56
18. To overcome Urban Noise	db	0	0	0	0
19. To overcome Rural Noise	db	0	0	0	0
20. Atmospheric Noise	db	9	9	0	0
21. Required Med. Field	dbuV/m	44	45	54	56
22. Rec. Ant. F/B ratio	db	6	6	12	12
23. D/U Ratio no offset	db	45	45	45	45
24. D/U Ratio offset	db	28	28	28	28
25. D/U Ratio Precise off	db	24	24	24	24
26. Adj. Chan. D/U Ratio (Low)	db	-6	-6	-6	-6
27. Adj. Chan. D/U Ratio (UP)	db	-12	-12	-12	-12

TABLE 4B

6. Receiver Noise Figures

The noise figures shown in the tables are averages of values found in Table 1 of a Hazeltine Research Report. (7/)

The Hazeltime values are shown in Appendix C.

7. Peak Visual Carrier/RMS Noise

Historically a figure of 30 db has been assumed. This is comparable to a TASO (8/) Grade 3 "passable" picture.

8. Transmission Line Loss

From TASO Table I, page 117, the losses for 50 ft of twinlead line are as follows;

	Low VHF	High VHF
New dry line	1 db	1 db
Old wet line	3 db	5 db

The values used in Tables 4A & 4B are an average of the best and worst case conditions of above.

9. Receiving Antenna Gain

The above values are taken from the Third Notice. TASO, Table I shows average gain values of 3.7 and 6.8 db above a 1/2 wave dipole for low VHF and high VHF respectively. A gain appears as a negative number in the tables 4A & 4B.

10. Dipole Factor

See Appendix A.

12. Local Field

The sum items 5, 6, 7, 8, 9, and 10. For Grade A this is the F(70,90) field and for Grade B, the F(50,90) field.

13. Location Probability Factor

These correction values are read from curve R(L) given in figure 1 above.

14. F(50,90) Field Strength

The sum of items 12 and 13.

16. Time Probability Factor

These values are derived from the propagation curves and the fading ratios of Appendix B as shown in Appendix D.

17. F(50,50) Field Strength

The sum of items 14 and 16.

18. Urban Noise Factor

The Urban Noise Factor is the increase in signal necessary to overcome the degradation caused by urban noise.

The Sixth Report & Order assumed values of 14 and 7 db at the Grade A contour for low VHF and high VHF respectively to overcome urban noise.

A CCIR document (9/), reports values of 20-30 db above thermal noise at 288 $^{\circ}K$ for low VHF and 10-15 db for high VHF in areas defined as business and residential sections of large cities as well as suburban areas of large population centers. This document, however, suggests that these figures be treated with caution until more evidence is available.

19. Rural Noise Factor

The Rural Noise Factor is the increase in signal necessary to overcome the degradation caused by rural noise.

The Sixth Report & Order assumed values of 0 db at the Grade B contour for all frequency ranges. Large population shifts, from cities to surburban areas, in many parts of the country, cause the Grade B contours in these areas to no longer lie in "rural" areas. The assumption of 0 db to overcome rural noise in these "rural areas" is probably no longer valid because of the increased number of high voltage power lines and motor vehicle traffic volume.

Preliminary studies, by the Systems Engineering Branch of OCE indicate values for man-made noise of 14 db on channel 3 in suburban areas. A CCIR document (9/) reports values of 15-20 db for low VHF in "rural" areas and 5-10 db for high VHF.

20. Atmospheric Noise

The value of 9 db for channels 2-6 is taken from a CCIR report. (10/)

21. Required Median Field

Normally, the required field is the sum of items 17 and a value to overcome noise based upon items 18, 19, and 20. Because of the uncertainty of the new values shown, the old assumed values of 14 and 7 db for Grade A and 0 db for Grade B service are being used.

22. Receiving Antenna Front to Back Ratio

For planning purposes, the values shown in table 4B are taken from C.C.I.R. Recommendation 419. (11/) Average values of 11.6 and 10.6 db are reported for low VHF and high VHF in the TASO Reports, Table I, page 117.

In the Sixth Report and Order the receiving antenna was assumed to be non-directional. This was intended to provide a margin of safety to permit optimum adjustment of the antenna for reception of several desired stations in different directions and to minimize reception of multipath signals and local oscillator radiation.

23-25 Desired-to-Undesired Ratios

For non-offset carriers, the Sixth Report & Order specified a desired-to-undesired ratio of 45 db. For offset carriers, 10,000 Hz ± 1,000 Hz, a 28 db ratio was specified.

The FCC Laboratory recently conducted tests* on TV channel carrier frequencies offset by 10,010 Hz (precise offset) and by zero Hz (synchronous visual carriers). When the data were analyzed in a manner somewhat analogous to one of the methods used by TASO, namely desired-to-undesired ratios vs. percentage of observations at each ratio, a ratio of 22 db for precise offset results in a picture "not worse" than the picture obtained from a ratio of 28 db for nominal offset carriers. This 22 db ratio is similar to results obtained in earlier tests conducted by the Lab and RCA, and with recent tests conducted by the Japan Broadcasting Corporation (NHK). (See page 11 of Appendix E). The data for the 0 Hz offset condition results in a ratio of 28 db. This indicates that there is no advantage in the picture quality of synchronous visual carriers over nominal 10,000 Hz offset carriers. The Laboratory report contains an alternate analysis which results in a ratio of 24 db for the precise offset condition.

The report points out that the tests were conducted with one co-channel undesired signal and that the 22 db ratio may not be valid when two co-channel undesired signals are present. Earlier tests by the Lab and RCA indicate that an additional 4 db of protection is needed when an additional co-channel signal is present. (See Appendix E. Page 12). Since precise offset is being considered in connection with the VHF drop-ins, where two co-channel undesired signals could be present, it is felt that the alternate analysis result of 24 db would offer better protection than the 22 db result. Therefore, the 24 db ratio is used in Table 4B for the Grade B contour. For the Grade A contour, a 70% location factor of 6 db is added which results in the 30 db ratio used for Table 4A.

26-27 Adjacent Channel Desired to Undesired Ratios

The original value for Grades A&B service was -6 db. Adding a 90% time fading factor of 6 db resulted in a time median ratio of 0 db.

The new values shown in Tables 4A & 4B are taken from CCIR recommendations, based upon TASO data.

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*The Laboratory report of these tests is attached as Appendix E to this report.

Conclusions

This review of the planning factors pertinent to the determination of service areas and separation distances in the VHF-TV service indicates that many of the original values are still valid. Updated values for some of the factors can be readily established. These include new receiver noise figures, co-channel desired-to-undesired signal ratios using precise frequency offset, and new adjacent channel desired-to-undesired ratios. The adoption of the new field strength curves also has a direct effect on the calculation of service and interference ranges.

Some of the changes suggested in this report are subject to further testing and/or policy decisions. These include the possible use of a man-made noise level in determining the Grade B contour and a receiving antenna front-to-back ratio in calculating co-channel interference.

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A P P E N D I X   A

Dipole Factor

The expression for the dipole factor is;

$$20 \log 10 \left[\frac{96.68}{F} \right] \qquad (1)$$

where, F = frequency in MHz.

The power available at the antenna terminals, Pa, is equal to the power density, P, times the effective area of the receiving antenna, A.

$$Pa(\text{watts}) = P \, \frac{(\text{watts})}{m^2} \, A(m^2) \qquad (2)$$

The maximum effective area of any antenna is given by;

$$A = \frac{G\lambda^2}{4\pi} \qquad (3)$$

where, G = the gain of the antenna relative to isotropic
λ = the wave length in meters

The power density is equal to;

$$P = \frac{E^2}{120\pi} \qquad (4)$$

where, E = field strength in V/m

The power delivered to any load is;

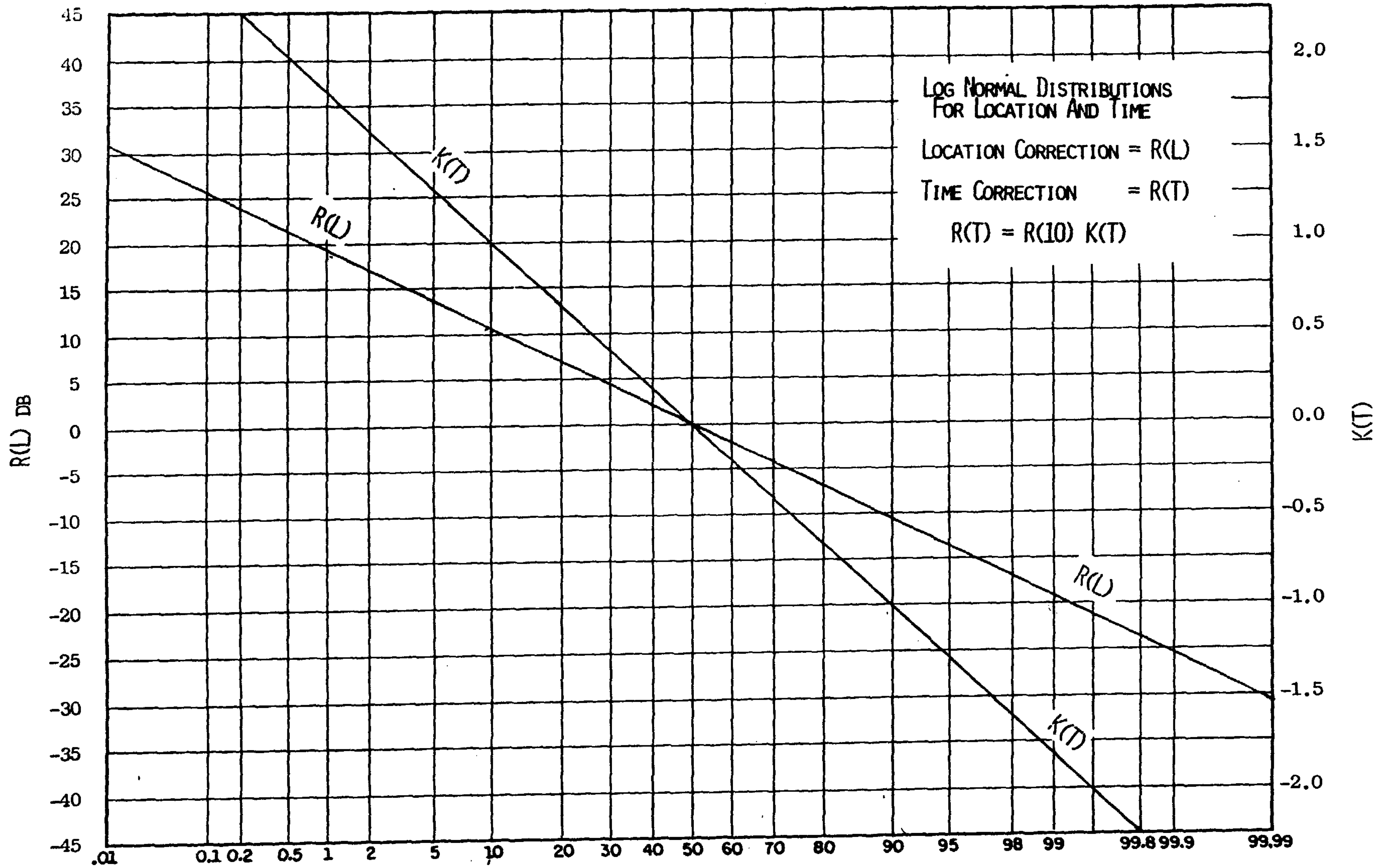
$$Pr = \frac{V^2}{R} \qquad (5)$$

Combining equations (2), (3), (4), and (5), and assuming that Pa = Pr by use of a matching transformer gives;

$$\frac{V^2}{R} = \frac{E^2}{120\pi} \, \frac{G\lambda^2}{4\pi} \qquad (6)$$

further assume; R = 300 ohms
G = 1.64
λ = 300/F,

where, F = frequency in MHz.



PERCENTAGE OF LOCATIONS, L, OR OF TIME, T, AT WHICH THE ORDINATE IS EXCEEDED

FIGURE 1